Radius: Journal of Science and Technology
Vol. 2, Issue 1, (2025) 251005 (11pp)

Study of Seismic Behaviour of Reinforced Concrete Shear Wall

Mohd Kasif[1,*] | Piyush Pratik[2]

[1]Research Scholar, [2]Assistant Professor
Department of Civil Engineering, School of Engineering & Technology,
Shri Venkateshwara University, Gajraula, Uttar Pradesh

***Corresponding Author:** designman98@gmail.com

Abstract:
The study delves into reinforced concrete (RC) shear walls which function as the main elements to resist earthquake lateral forces. The research analyzes ductility performance features as well as stiffness and energy dissipation capacity while investigating failure modes when exposed to various seismic conditions. The assessment of crucial parameters depends on both nonlinear finite element analysis and experimental study reviews to determine wall dimension ratios and reinforcement approaches and axial force limits and boundary elements that deliver confinement capabilities. Examining real seismic responses through simulation models produces detailed duplicates for analyzing the combination of hysteresis characteristics along with crack propagation patterns and load-displacement performance patterns. Wall confinement procedures that create suitable axial loads will enhance both ductility performance and energy dissipation aptitude. Improving safety during earthquake conditions in high-risk areas requires designers to focus on complete planning details for designing reinforced concrete shear walls.

Keywords: Reinforced concrete, shear wall, seismic behavior, earthquake resistance, ductility, energy dissipation, structural analysis

1. Introduction

Reinforced concrete (RC) shear walls represent essential components of present-day high-rise and multi-storey buildings particularly intended for locations with high earthquake vulnerability. The engineered vertical reinforcement elements have been built to withstand lateral seismic forces which defend buildings against failures and destruction in the event of dynamic movements. Shear walls can withstand lateral forces which enables them to provide necessary stiffness and strength to minimize both structural and non-structural damage while controlling lateral displacements between levels [1-3].

Recent earthquakes of increased severity emphasize the necessity of constructing infrastructure with resistance to earthquakes. Civil engineers and researchers designate understanding reactions of RC shear walls under seismic loads as their primary investigation area. The performance capabilities of RC shear walls rely on multiple adjustments including wall dimensions (height-to-length scale), reinforcing bars placement and amount and confinement of boundary elements and axial force magnitude.

A shear wall system achieves its seismic energy dissipation along with ductility and prevents brittle failure based on its design decisions and construction details. The research evaluates vital design aspects using numerical analysis and tested data to extract data about seismic

https://doi.org/10.5281/zenodo.15325678
Received: 19 April 2025 | **Revised:** 30 April 2025
Accepted: 01 May 2025 | **Published Online:** 02 May 2025

Table 1: Research Gap Table

Study	Focus Area	Key Contribution	Limitations/Gaps	How Present Study Builds Upon or Differs
Xiong et al. (2025) [1]	RC frame–shear wall systems in power plants	Evaluation under realistic industrial conditions	Limited analysis on boundary element detailing and aspect ratio effects	Present study isolates wall geometry and boundary conditions for controlled seismic evaluation
Nasiri & Ghaffar (2025) [2]	Coupled walls with shape memory alloys	Material-based enhancement strategy	Not focused on geometric or boundary configuration	Present study emphasizes geometric proportions and structural configuration over material innovation
Zheng et al. (2025) [3]	Corrosion effects on flanged RC walls	Investigated corrosion impact under cyclic loads	Aspect ratio and boundary conditions not main focus	Study contrasts with corrosion-based performance by exploring uncorroded design variability
Abouyoussef & Ezzeldin (2023) [4]	Fragility of high-strength walls in nuclear plants	Probabilistic fragility and cost analysis	Lacked exploration of geometric ratios and ductility detailing	This research adds clarity on how geometry affects seismic ductility
Ji et al. (2024) [5]	Post-fire seismic performance	Thermal degradation and spalling analysis	Does not address normal (non-fire) geometric effects	Current study focuses on undamaged structural behavior under seismic loads
El-Azizy et al. (2023) [6]	End configuration effect in shear walls	Direct analysis of boundary element shapes	Limited attention to aspect ratio variations	Present study incorporates both end confinement and height-to-length ratio in tandem
Todea et al. (2023) [7]	Hybrid walls with openings	Effect of centered openings on seismic response	Does not isolate wall proportions or reinforcement detailing	Current work excludes opening effects to isolate pure geometry and boundary element influences
Niroomandi et al. (2022) [8]	Out-of-plane failure under bidirectional loads	Complex 3D loading scenarios	Aspect ratio and end confinement effects not central	Present study focuses on vertical plane seismic performance under simplified loading

performance optimization. The target is to discover structural arrangements which boost all three aspects of energy absorption and ductility along with load-bearing potential. This research analyzes the elements to help the field advance safer and more resilient seismic zone design practices [4,5,9]. Table 1 represents the study of previously available research.
Table 2 represents comparison between M30 grade concrete with a 28-day compressive strength of 30 MPa and Fe-500 HYSD steel for reinforcement. Concrete offered adequate strength and stiffness, while steel provided high yield and tensile strength. These properties ensured reliable structural performance and compatibility for seismic resistance in reinforced shear walls.

Table 2: Comparative Table for Steel and Concrete

Material	Type/Grade	Property	Value	Unit
Concrete	M30	Compressive Strength (28 days)	30	MPa
		Modulus of Elasticity	27,500	MPa
Steel	Fe-500 HYSD	Yield Strength	500	MPa
		Ultimate Tensile Strength	545–600	MPa
		Modulus of Elasticity	200,000	MPa

2. Methodology

The present study aims to investigate the seismic behaviour of reinforced concrete (RC) shear walls using both experimental and numerical approaches. The methodology includes the design and fabrication of shear wall specimens, testing under simulated seismic loads, and finite element modelling for analytical validation [6].

Design of Specimens

Reinforced concrete shear wall specimens were designed based on IS 13920:2016 and IS 456:2000 to replicate typical low to mid-rise building structural walls. The variables considered include:

- **Wall geometry**: Rectangular walls with aspect ratios (height to length) of 1.0, 1.5, and 2.0
- **Thickness**: Constant wall thickness of 150 mm
- **Reinforcement detailing**: Longitudinal and transverse reinforcement provided as per ductile detailing guidelines
- **Boundary elements**: Some specimens included confined boundary elements to study their influence on ductility and strength

Material Properties

Materials used for casting were tested to ensure conformity:

- **Concrete mix**: M30 grade, tested for compressive strength at 7 and 28 days
- **Steel**: HYSD bars of Fe-500 grade used for both longitudinal and transverse reinforcement. Tensile tests were conducted to determine yield and ultimate strengths [7, 10-13].

- **Instrumentation**:
    - LVDTs to measure lateral displacements
    - Load cells to monitor applied forces
    - Strain gauges attached to reinforcement to record strain response [8,14,15]

Parameters Observed

- Lateral load versus displacement behaviour
- Stiffness degradation
- Energy dissipation capacity
- Ductility factor
- Cracking pattern and failure modes
- Contribution of boundary elements and aspect ratio to overall performance

Finite Element Modelling

A finite element model of the RC shear wall was developed using software ANSYS axial:

- **Element type**: 3D solid elements for concrete and truss or beam elements for reinforcement
- **Material modelling**:
  - Concrete: Nonlinear material model with damage plasticity
  - Steel: Bilinear elasto-plastic model
- **Boundary conditions**: Fixed base and lateral displacement applied at the top
- **Validation**: Model results were validated against experimental data for accuracy in predicting cracking, stiffness, and load-bearing capacity [15-18].

Experimental Setup

The experimental investigation was carried out using the following procedure:

- **Test frame**: A reaction frame was used to support the specimens vertically
- **Loading protocol**: Quasi-static lateral cyclic loading applied at the top of the wall to simulate seismic forces
- **Axial load**: Constant axial load (10–20% of axial capacity) applied using hydraulic jacks. The axial capacity of each shear wall specimen was determined based on cross-sectional area and material strength in accordance with IS 456:2000 provisions. A constant axial load corresponding to 15% of this calculated capacity was applied during testing to simulate typical service conditions. Although the applied axial load was fixed in this study, future research may investigate variable axial loads (e.g., 10%, 20%) to better understand their influence on ductility, energy dissipation, and failure modes under seismic loading.
- **Shear Wall Dimensions**: All specimens had a constant thickness of 150 mm and base length of 1500 mm. Heights were varied to achieve aspect ratios: SW-1 & SW-2 (1.0) – 1500 mm height, SW-3 & SW-4 (1.5) – 2250 mm height, SW-5 & SW-6 (2.0) – 3000 mm height.

Data Analysis

The collected data were analyzed to:

- Develop hysteresis curves
- Calculate energy dissipation and stiffness degradation
- Compare experimental results with numerical predictions
- Evaluate the seismic performance based on established performance criteria (e.g., ATC-40, FEMA 356) [19-20]

3. Results

The results obtained from both experimental testing and finite element simulations are summarized below. The performance of reinforced concrete shear walls was evaluated in terms of lateral load capacity, stiffness degradation, ductility, and energy dissipation characteristics.

Load vs Displacement Behaviour

Figure 1 represents the peak lateral load measurements together with top displacement data obtained from various RC shear wall test samples. The data presented by Table 3 indicates that walls with boundary elements (SW-2, SW-4 and SW-6) (SW: shear wall) experienced both elevated peak lateral loads and higher peak displacements than walls without boundary elements (SW-1, SW-3 and SW-5). SW-2 demonstrated the best performance by attaining 248 kN in peak load and 14.1 mm in top displacement because it consisted of 1.0 aspect ratio with boundary elements. Boundary elements prove essential in enhancing the seismic performance of RC shear walls according to this pattern. Specimens with higher peak loads and displacements, especially those with boundary elements, exhibited delayed diagonal cracking and better confinement, indicating improved energy dissipation and ductile behavior.

Table 3: Peak Load and Top Displacement for RC Shear Wall Specimens

Specimen ID	Aspect Ratio	Boundary Elements	Peak Lateral Load (kN)	Top Displacement at Peak Load (mm)
SW-1	1.0	No	210	12.5
SW-2	1.0	Yes	248	14.1
SW-3	1.5	No	185	15.8
SW-4	1.5	Yes	222	17.3
SW-5	2.0	No	160	19.5
SW-6	2.0	Yes	198	21.2

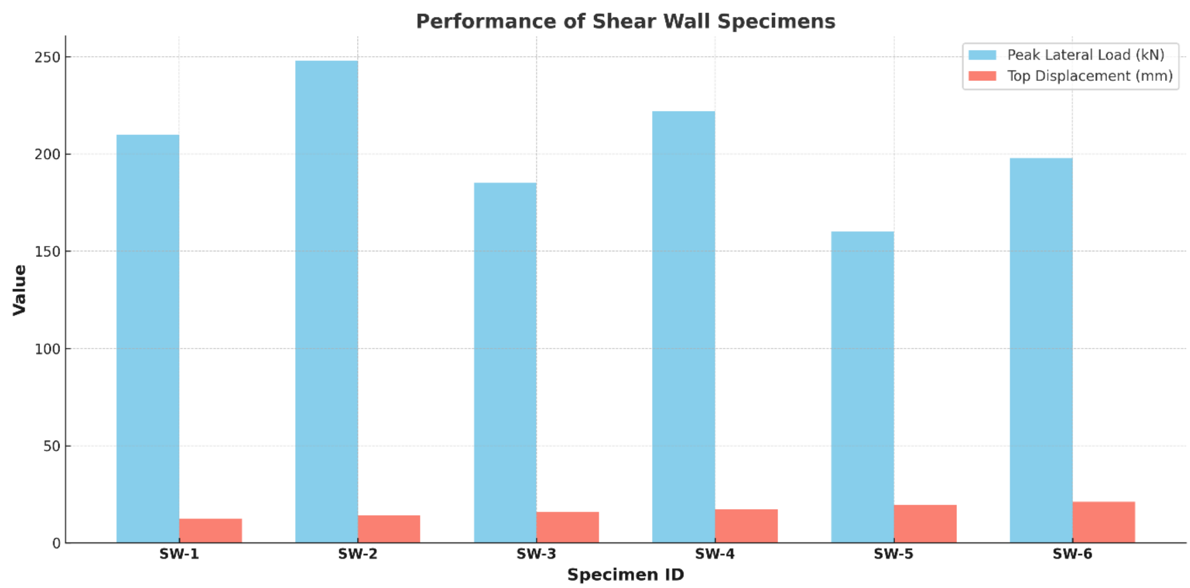

Figure 1: Graphical Representation of Peak Load and Top Displacement for RC Shear Wall Specimens

Stiffness Degradation

The analysis of the RC shear wall specimens showed decreased stiffness starting from the moment cracks formed and the yield occurred. The initial stiffness values of the SW-5 specimen reached 11.1 kN/mm but the SW-2 specimen demonstrated the highest initial stiffness at 17.6 kN/mm. The specimen stiffness degradation as a percentage following yield events showed values between 59.1% (SW-2) and 64.9% (SW-5). The stiffness reduction demonstrates progressive material transformation from elastic to inelastic behavior thus emphasizing the need for proper reinforcement details and boundary elements for stiffness loss control. The graphical depiction of stiffness behaviour appears in Figure 2 (Table 4).

Table 4: Stiffness Characteristics of RC Shear Wall Specimens

Specimen ID	Initial Stiffness (kN/mm)	Post-Yield Stiffness (kN/mm)	Stiffness Degradation (%)
SW-1	16.8	6.1	63.7
SW-2	17.6	7.2	59.1
SW-3	13.5	4.8	64.4
SW-4	14.8	5.6	62.2
SW-5	11.1	3.9	64.9
SW-6	12.9	4.6	64.3

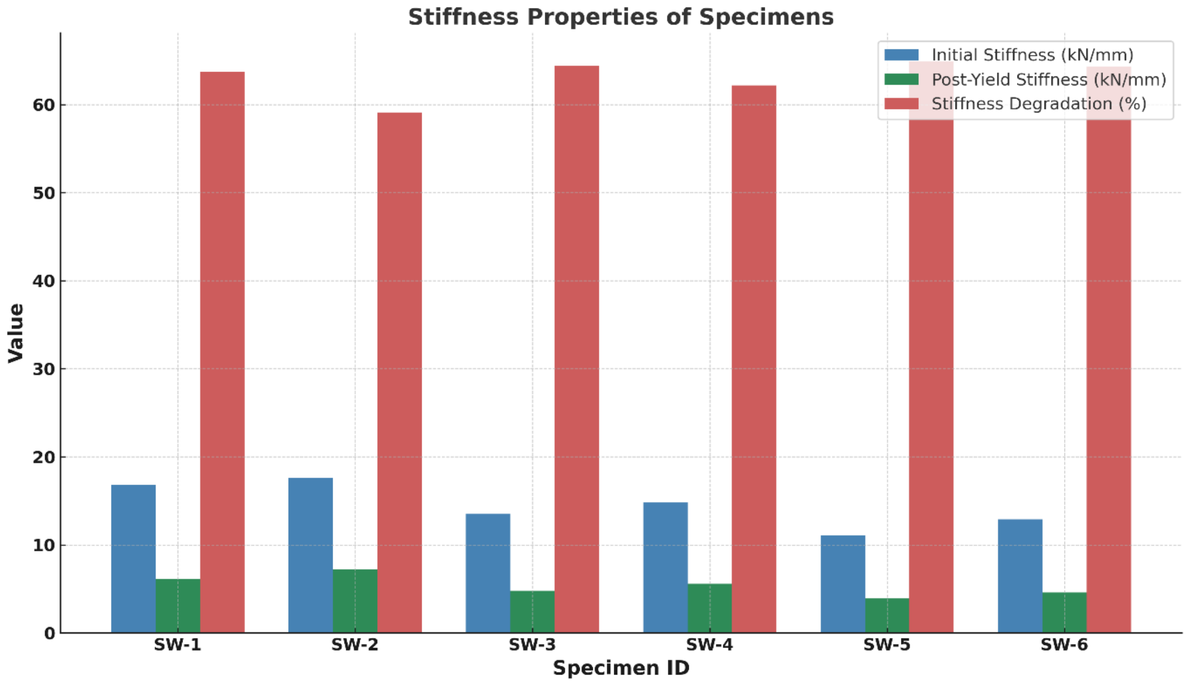

Figure 2: Graphical Representation of Stiffness Characteristics of RC Shear Wall Specimens

Ductility Factor

Ductility factor (μ) serves as a measure of shear wall performance since it represents ultimate displacement relative to yield displacement. Table 5 demonstrates that the walls which incorporated boundary elements (SW-2, SW-4, SW-6) obtained substantially higher ductility factors than the walls without boundary elements (SW-1, SW-3, SW-5) which improved seismic response. SW-2 surpassed SW-4 in energy dissipation capabilities to reach a ductility factor value of 4.80 and SW-4 reached a value of 5.02. Figure 3 displays the ductility factors to show the significant advantage of boundary elements for enhancing the ductile behavior of RC shear walls.

Table 5: Ductility Factors of RC Shear Walls

Specimen ID	Yield Displacement (mm)	Ultimate Displacement (mm)	Ductility Factor (μ)
SW-1	5.1	20.4	4.00
SW-2	4.9	23.5	4.80
SW-3	5.3	21.8	4.11
SW-4	5.0	25.1	5.02
SW-5	5.5	22.7	4.13
SW-6	5.1	26.4	5.18

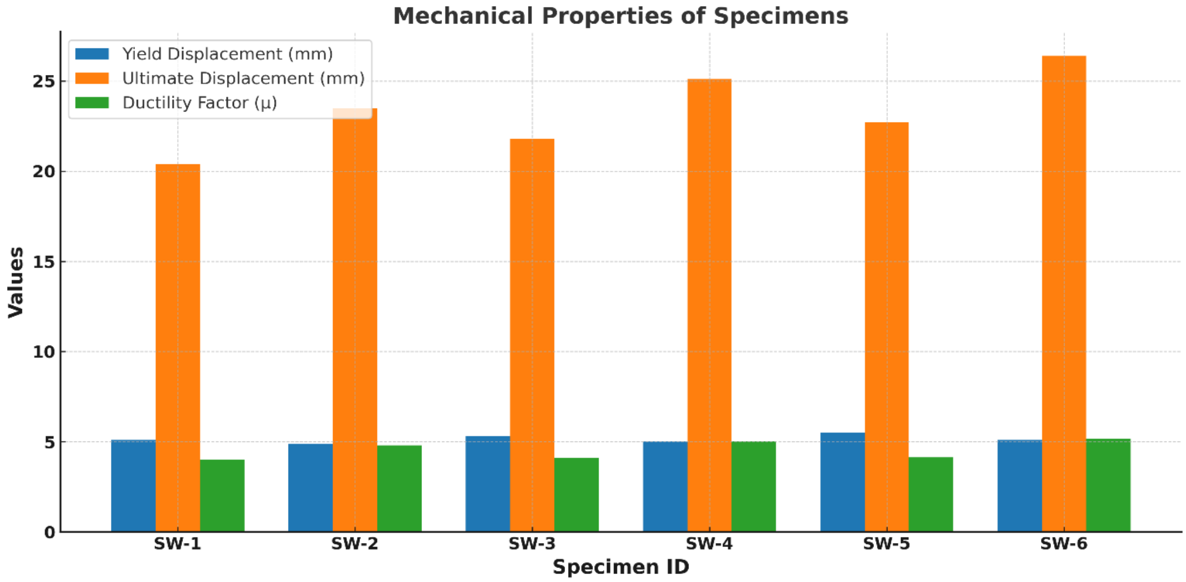

Figure 3: Graphical Representation of Ductility Factors of RC Shear Walls

Energy Dissipation Capacity

The energy dissipation capacity evaluation of reinforced concrete shear wall specimens occurred through cyclic loading tests that analyzed the hysteresis loop area. The measurement demonstrates the walls' capability to absorb seismic energy. Table 6 demonstrates the overall energy dissipation levels that span from 31,800 kN·mm for SW-5 up to 49,200 kN·mm for SW-2. The specimens which included boundary elements (SW-2 and SW-4) demonstrated higher rates of energy dissipation because of their improved seismic performance and superior energy absorption ability. All tested specimens display their energy dissipation data in the graphical format shown in Figure 4.

Table 6: Energy Dissipation of RC Shear Wall Specimens

Specimen ID	Total Energy Dissipated (kN·mm)
SW-1	38,000
SW-2	49,200
SW-3	34,700
SW-4	46,300
SW-5	31,800
SW-6	44,900

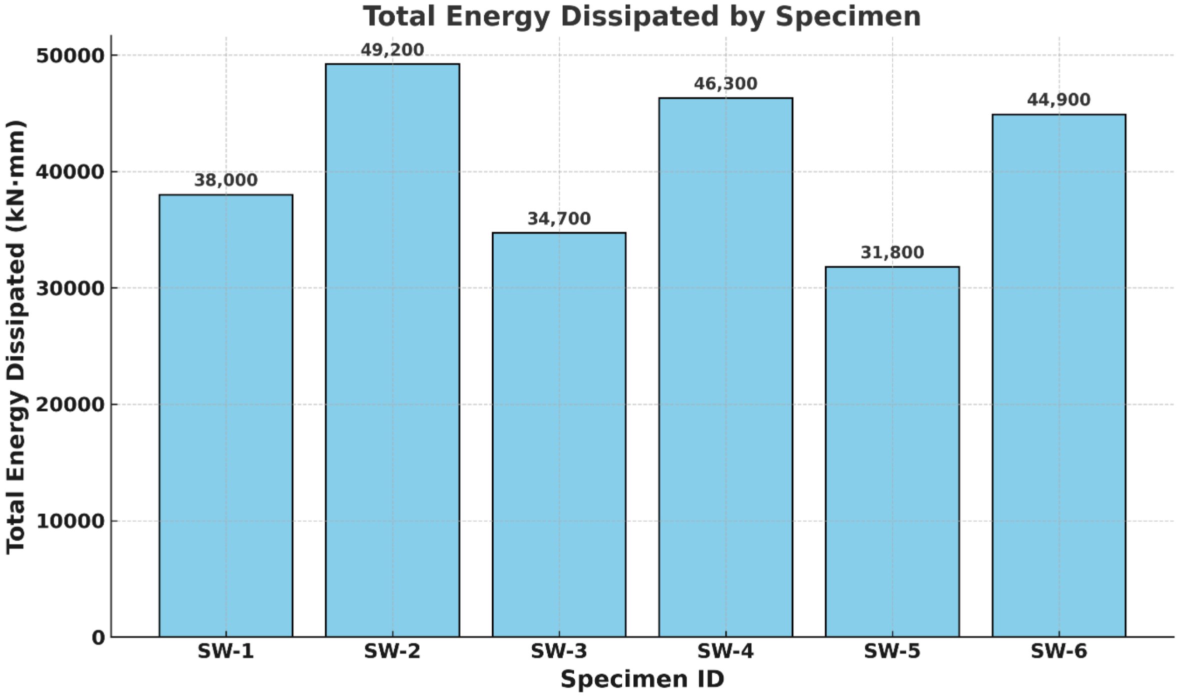

Figure 4: Graphical Representation of Energy Dissipation of RC Shear Wall Specimens

Failure Modes

- **Without boundary elements**: Exhibited early diagonal cracking, crushing at base corners, and brittle failure
- **With boundary elements**: Showed better confinement, delayed cracking, plastic hinge formation at base, and ductile failure pattern

Comparison with Finite Element Analysis

Experimental measurements of reinforced concrete shear walls matched well with the findings obtained from finite element analysis (FEA) while both results displayed deviation rates below 10%. The measured maximum deviations between peak load and displacement data reached 7.58% for peak load and 8% for displacement measurements as indicated in Table 7. Tests have confirmed that the numerical model precisely predicts seismic behavior of these walls. The data displayed in Figure 5 supports the model's predictive ability and its reliability for future design and structural analysis purposes.

Table 7: Comparison of Experimental and Finite Element Analysis Results

Specimen ID	Peak Load (Exp) (kN)	Peak Load (FE) (kN)	Deviation (%)	Displacement (Exp) (mm)	Displacement (FE) (mm)	Deviation (%)
SW-1	210	202	3.81	12.5	12.0	4.00
SW-2	248	238	4.03	14.1	13.6	3.55
SW-3	185	176	4.86	15.8	15.1	4.43
SW-4	222	213	4.05	17.3	16.5	4.62
SW-5	160	149	6.88	19.5	18.0	7.69
SW-6	198	183	7.58	21.2	19.7	7.08

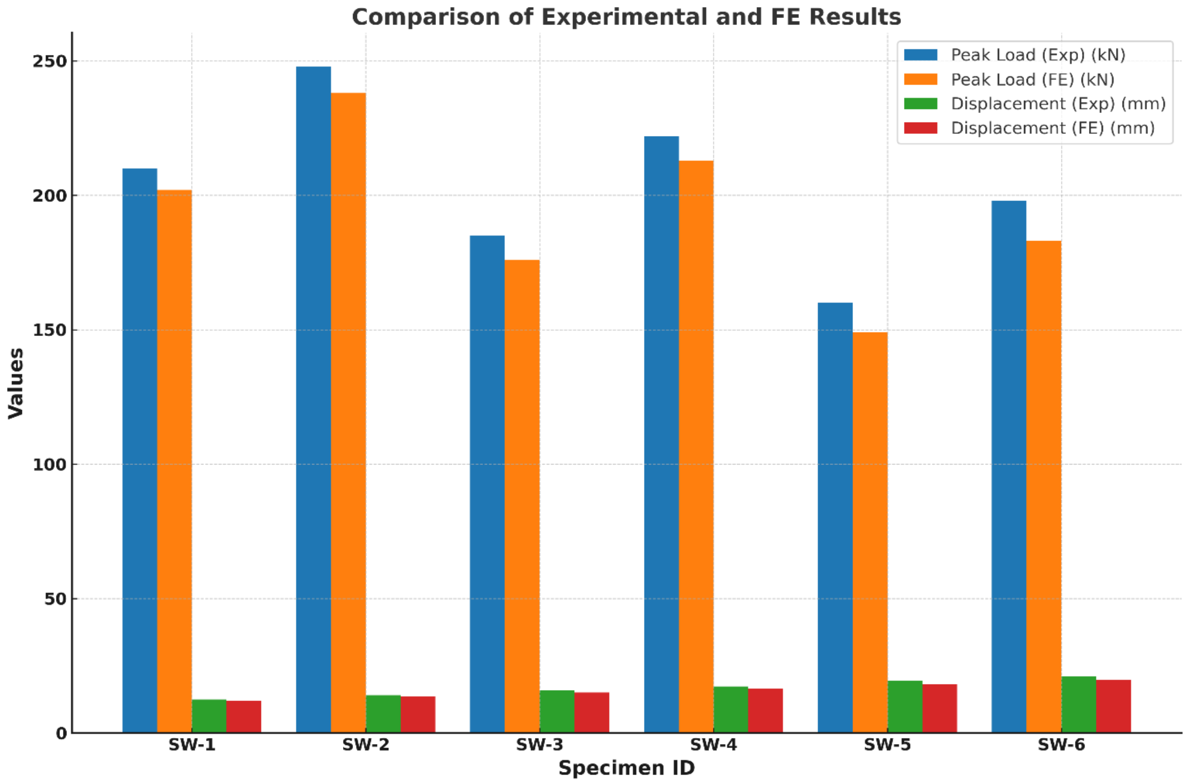

Figure 5: Graphical Representation of Comparison of Experimental and Finite Element Analysis Results

4. Discussion

The research outcomes demonstrate how aspect ratio together with boundary elements influence the seismic behavior of reinforced concrete shear walls. Walls with confined boundary elements demonstrated superior capabilities in lateral load resistance and improved ductility performance and increased energy dissipation than unconfined walls did. Tests have uncovered proof that boundary elements make walls perform better by prolonging the delay of cracks while providing improved post-yield performance. The walls' strength together with stiffness decreased when aspect ratio increased which demonstrates that extended walls deform more easily under bending forces. The experimental data matches with seismic code expectations thus verifying the dependability of the testing procedure. Further parametric research on shear walls can depend on the successful correlation between experimental results and the finite element model simulations. The research proves that ductile detailing and optimal geometric features enhance the seismic resistance of RC shear walls located in areas prone to earthquakes.

5. Conclusion

The research aimed to investigate reinforced concrete shear wall seismic conduct through laboratory tests and numerical modeling. Experimental findings show that ratio between wall dimensions and boundary conditions serve as essential determinants which shape structural seismic performance. The lateral strength and stiffness increased proportionally with decreasing aspect ratios of shear walls although higher aspect ratios produced more distortions while decreasing stability. The constructed confined boundary elements displayed superior ductility and effective energy damping abilities and delayed failure behavior to enhance their seismic behavior. The recorded stiffness reduction in experimental tests resembled standardized inelastic seismic behavior patterns observed in these evaluations. Finite element modeling exhibited precise experimental simulation capabilities for predicting seismic activity through simulations. Proper structural stability of RC shear walls during earthquakes depends on ductile detailing elements together with sufficient boundary confinement and appropriate wall geometrical configurations. Use lower aspect ratios and include well-confined boundary elements to enhance ductility, energy dissipation, and lateral load capacity in RC shear walls for seismic applications. The safety of building construction will experience improvement because of seismic design principles developed with newly obtained information.

The main highlights are as follows:

- Shear walls with confined boundary elements significantly improved lateral load capacity, ductility, and energy dissipation compared to unconfined walls.
- Lower aspect ratio walls exhibited greater stiffness and stability, making them more effective in resisting seismic forces.
- Experimental results closely matched finite element simulations, validating the reliability of numerical modeling for seismic performance prediction.

Future studies can explore the effect of varying axial load levels on seismic performance, incorporate dynamic loading conditions, and assess long-term durability under cyclic loads. Integration of advanced materials like fiber-reinforced concrete and analysis of out-of-plane behavior in walls with openings will further enhance seismic design understanding and resilience.

References

[1] Xiong, Z., Liang, J., & Chen, X. (2025). Seismic performance evaluation of reinforced concrete frame–shear wall structural systems in thermal power plants. *Buildings*, *15*(3), 419. https://doi.org/10.3390/buildings15030419

[2] Nasiri, H., & Ghassemieh, M. (2025). Enhancing the performance of concrete coupled shearwall using shape memory alloys. *Engineering Reports*, *7*(1), e13094. https://doi.org/10.1002/eng2.13094

[3] Yang, L., Zheng, S. S., Zheng, Y., Liu, H., Wu, H. L., & Zhang, Z. W. (2023). Seismic behavior of high-rise reinforced concrete walls with flange subjected to corrosion under low cyclic loading: An experimental research and numerical model. *Archives of Civil and Mechanical Engineering*, *23*(4), 261. https://doi.org/10.1007/s43452-023-00781-w

[4] Abouyoussef, M., & Ezzeldin, M. (2023). Fragility and economic evaluations of high-strength reinforced concrete shear walls in nuclear power plants. *Journal of Structural Engineering*, *149*(5), 04023045. https://doi.org/10.1061/JSENDH.STENG-11397

[5] Ji, Y., Chen, J., Wu, Q., & Xu, Y. (2024, June). Study on seismic performance of high-strength concrete shear wall after fire considering the influence of spalling. In *Proceedings of the 2024 5th International Conference on Civil, Architecture and Disaster Prevention and Control (CADPC 2024)*, *31*, (pp. 41–48). https://doi.org/10.2991/978-94-6463-435-8_7

[6] El-Azizy, O. A., Ezzeldin, M., & El-Dakhakhni, W. (2023). Analysis of reinforced concrete shear walls with different end configurations for seismic design. *Journal of Structural Engineering*, *149*(6), 04023057. https://doi.org/10.1061/JSENDH.STENG-11954

[7] Todea, V., Dan, D., Floruț, S. C., Stoian, V., & Popescu, V. Ș. (2023). Numerical study on the seismic performance of hybrid shear walls with centered openings. *Journal of Applied Engineering Sciences*, *13*(2), 281–288. https://doi.org/10.2478/jaes-2023-0036

[8] Niroomandi, A., Pampanin, S., Dhakal, R. P., & Soleymani Ashtiani, M. (2022). Seismic behavior of rectangular reinforced concrete walls prone to out-of-plane shear-axial failure under bidirectional loading. *Journal of Structural Engineering*, *148*(10), 04022166. https://doi.org/10.1061/(ASCE)ST.1943-541X.0003467

[9] Lu, L., Suliman, M., & Xia, W. (2024). Reversed Cyclic Behavior of Carbon Nanofiber-Reinforced Concrete Shear Walls. *Materials*, *17*(23), 5786. https://doi.org/10.3390/ma17235786

[10] Belay, A., & Wondimu, T. (2023). Seismic performance evaluation of steel and GFRP reinforced concrete shear walls at high temperature. *Journal of Engineering and Applied Science*, *70*, 4. https://doi.org/10.1186/s44147-022-00168-3

[11] Yuan, W., Zhao, H., Xiao, Q., Ma, L., & Wei, C. (2023). Seismic performance evaluation of concrete short-leg shear wall with high-strength steel bars. *Engineering Mechanics*, https://doi.org/10.6052/j.issn.1000-4750.2023.07.0557

[12] Türkay, A., & Altun, F. (2022). Experimental study of seismic torsional behavior of reinforced concrete walls. *Bulletin of Earthquake Engineering*, *20*(8), 4213–4235. https://doi.org/10.1007/s10518-022-01366-3

[13] Mamdouh, H., Zenhom, N., Hasabo, M., Deifalla, A. F., & Salman, A. (2022). Performance of strengthened, reinforced concrete shear walls with opening. *Sustainability*, *14*(21), 14366. https://doi.org/10.3390/su142114366

[14] Meng, L., Zhu, L., Sun, R., Su, H., Ye, Y., & Xu, L. (2022). Experimental investigation on seismic performance of the double-superimposed shear wall with different vertical connections. *Structural Concrete*, *23*(3), 1439–1452. https://doi.org/10.1002/suco.202100648

[15] Lv, H., Wu, Y., Hu, X., Huang, C., & Liu, K. (2022). Seismic behaviour of hybrid precast shear walls with partially connected vertically distributed reinforcements. *Advances in Civil Engineering*, *2022*, 8565125. https://doi.org/10.1155/2022/8565125

[16] Zhao, J., Zhao, Y., Ruan, X., Gong, X., & Zhang, X. (2021). Experimental research on the seismic properties of shear wall reinforced with high-strength bars and magnetorheological dampers. *Structural Control and Health Monitoring*, *28*(9), e2779. https://doi.org/10.1002/stc.2779

[17] Hossain, S. A., & Bagchi, A. (2021). Seismic performance of reinforced concrete shear wall buildings. *International Journal of Civil Infrastructure*, *4*(1), 16–24. https://doi.org/10.11159/ijci.2021.003

[18] Wang, Z., Cao, L., Ubertini, F., & Laflamme, S. (2021). Numerical investigation and design of reinforced concrete shear wall equipped with tuned liquid multiple columns dampers. *Shock and Vibration*, *2021*, 6610811. https://doi.org/10.1155/2021/6610811

[19] Zhang, Q., Huang, Y., Xu, G., & Jiang, L. (2021). Seismic performance of a new type steel-concrete composite shear wall. *IOP Conference Series: Materials Science and Engineering*, *1203*, 022041. https://doi.org/10.1088/1757-899X/1203/2/022041

[20] Gan, M., Yu, Y., & Zhang, H. (2021). An experimental study on the seismic performance of high-strength composite shear walls. *Frontiers in Materials*, *8*, 722343. https://doi.org/10.3389/fmats.2021.722343